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F.A. REPORT NO. R 1148

O.O. Project No. TA1 5003





*Charles R Iannotti*
*project engineer*



February 1954

Artillery Ammunition Department • Frankford Arsenal, Philadelphia, Pa.



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90 mm FIN STABILIZED
APDS PIERCING SHOT
Sabot Discarding
ARTILLERY AMMUNITION DEPARTMENT · FRANKFORD ARSENAL

REPORT NO R-1184

# DEVELOPMENT OF 90MM SHOT, (ARMOR PIERCING), FIN-STABILIZED DISCARDING SABOT, FOR THE DEFEAT OF ARMOR

O.O. PROJECT NO: TA1-5003

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# 20MM SHOT, ARMOR PIERCING, FIN STABILIZED DISCARDING SABOT

## CONTENTS

I

## PREFACE

The idea of an arrow shot for use as an armor penetrator has occurred to many people in the past. Unsuccessful tests have been conducted with this type of shot in 1950, after which it was the general opinion that this type of shot would not give satisfactory performance.

In recent months Mr. Croskery of OCO, ORDTA and Mr. Iannotti of Frankfori Arsenal discussed the resumption of a similar program, but this time stressing the importance of increased velocity and the desirability of high cross-sectional density.

Mr. Lipinski of Frankford Arsenal encouraged the resumption of this program, feeling that no definite conclusions could be drawn concerning the potential of arrow shot as an armor penetrator unless it were fired under optimum conditions. Firing from a smooth bore gun is considered to approach optimum conditions.

After discussions among Mr. Croskery of OCO, ORDTA, Mr. H. Lipinski and Mr. C. Iannotti of Frankford Arsenal, and Mr. H. Bechtol and Lt. R. Riel of Development and Proof Services, Aberdeen Proving Ground, a program was set up in March 1953 for the development of such a round. This program, set up under Project TA1-5003, called for the development of a 90mm

fin-stabilized discarding-sabot armor-piercing shot for use in the 90mm T119 gun. Mr. G. Croskery stated that Frankford Arsenal should strive to design a round that would defeat four (4) inches and possibly five (5) inches of rolled homogeneous armor plate at 60° obliquity at 2000 yard range.

This report covers the progress made to date in the development of the 90mm fin stabilized discarding sabot armor piercing shot under Frankford Arsenal Development Engineering Program 2[illegible].

II

## PROGRAM OBJECTIVES

Based on the data which is available, the following are objectives which seem to be realistic and which should be considered:

Objective A - The immediate objective - Developing a projectile which will defeat four (4) inches of homogeneous armor plate at 55° obliquity at a range of 2000 yards and four (4) inches of homogeneous armor plate at 60° obliquity at a range of 1000 yards, fired from a rifled 90mm T119 gun.

Objective B - To defeat six (6) inches of homogeneous armor at 60° obliquity at a range of 2000 yards using an improved 90mm smooth bore gun with an improved ignition system.

III

## SUMMARY

The following report covers the development of Fin Stabilized Arrow Shot. The results achieved to date with the arrow projectile forecast a complete change in attitude toward ammunition design and tank design. It appears possible that the present standard 90mm tank gun utilizing the arrow shot might outperform the 120mm tank gun utilizing the 120mm conventional shot. It is now possible and probable that our medium tanks might defeat the heaviest tanks the enemy can put in the field.

At the present time, the velocity of the arrow projectile is approximately 4300 fps when fired from a 90mm smooth bore M3A1 gun when fired at a pressure of 47,000 psi. Designs are being developed which may result in muzzle velocities above 5000 fps in the T119 Gun. Increasing velocity will increase the effectiveness of the gun in the following ways:

1. In unaided (no fire control) fire aimed at a stationary or moving target, it increases the allowable error in estimating range without reducing the probability of hitting because of decreased time of flight.

2. In unaided fire aimed at a moving target, it reduces the necessary lead angle. Since the allowable absolute error in lead angle is independent of the lead and since the absolute accuracy of estimating lead improves with reduced lead angles, the probability of hitting is improved because of decreased time of flight.

3. In director-controlled fire against a maneuvering target, the probability of hitting is greatly increased by attaining an increase in velocity; since the region within which the target can maneuver during the time of flight is diminished in volume.

In order to minimize firing stressed in the shot caused by a reduction in diameter, new principles of launching are being studied. At the present time, the potentials of a penetrator of this type of round have as yet not been determined.

In production quantities, the arrow shot is far more economical than an HVAPDS with a light weight carrier and much more economical than a comparable fin-stabilized HEAT projectile.

The arrow shot is more reliable, since its function as a penetrator can be measured in terms of the reliability of the primer; while the reliability of HEAT rounds depends

on primer, fuze, and cone function; and the HVAP depends on stability and rotational velocity. Because of the high muzzle velocity of the projectile, the probability of first round hit is higher for this type of projectile.

IV

## CONCLUSIONS

On the basis of the progress made to date in the development of the APFSDS shot, the following conclusions have been drawn:

1. A new theory of penetration of armor by armor piercing shot has been established.

2. Four (4) inches of rolled homogeneous armor plate at 55° obliquity at 2000 yards, or four (4) inches at 60° obliquity at 1000 yards can be defeated using the present 90mm T119 rifled gun.

3. Five (5), or possibly six (6) inches of rolled homogeneous armor plate at 60° obliquity at 2000 yards could be defeated with an improved 90mm smooth bore gun system.

4. Smooth bore tank weapons will lead to improved interior, exterior and terminal ballistics for tank ammunition.

5. From a stress point of view the fin stabilized shot can be launched at higher velocities than a spin stabilized shot.

6. The probability of a first round hit is greater with a fin stabilized shot than with a spin stabilized shot.

7. A complete family of fin stabilized ammunition for a 90mm smooth bore gun is feasible.

8. Fin stabilized ammunition will perform much better in a smooth bore than in a rifled gun.

9. The cost of a fin stabilized shot is much cheaper than a HEAT projectile or an HVAP shot. Following is cost estimate of each type of projectile:

a. FSDS - $25

b. HVAPDS - $125

c. HEAT - $40

10. If the T82E22 shot body were fired from the 76mm T91 gun, it would be possible to defeat three (3) inches at 55° at 2000 yards or three (3) inches at 60° at 1000 yards.

11. If the T82E22 shot body were fired from the 105mm T140 gun, it would be possible to defeat six (6) inches of rolled homogeneous armor plate at 55° at 2000 yards or six (6) inches at 60° at 1000 yards.

V

## INTRODUCTION

The development of the FSDS type armor piercing shot was undertaken by the Artillery Ammunition Department of Frankford Arsenal in an attempt to obtain a marked increase in the armor penetration of kinetic energy projectiles. We did not believe that changes in ogive contour or metallurgical characteristics would give a marked improvement in penetration characteristics. It was believed that a projectile with a higher cross-sectional density and one which would be fired at higher velocities (4200 ft/sec min.) than those velocities obtained with present armor piercing shot would have to be designed in order to give any marked increase in penetration.

The available energy developed by the APFSDS shot as it strikes the armor plate is considerably higher than that created by any kinetic energy projectile, including carbide cores, developed to date. Present penetration tests, which holds up fairly well for spin stabilized projectiles, are completely inadequate to explain the phenomenon which takes place. Apparently, in the initial stages of penetration, the FSDS shot disintegrates, also disintegrating the target material in front of it; creating tremendous local pressure

and generating vast quantities of heat so that in the later stages of penetration the shot actually is punching through a relatively soft material which folds back in layers. The phenomenon approaches that of a shaped charge in penetrating armor plate. The velocity of the jet from a HEAT shell is approximately 10,000 to 30,000 fps, but because of the large masses involved by comparison with the FS shell, the local pressures begin to approach those attained by HEAT projectiles. Programs are being planned now to test lighter and heavier projectiles at higher velocities in order to determine whether or not there is a change in phenomenon as the energy levels increase.

APFSDS T82 Arrow Shot

The length over diameter ratio of the 90mm T82 Shot has, by firing tests, been determined to be optimum or nearly optimum. The 90mm T82E22 design is approximately four (4) inches shorter than the E16 design and lighter by two (2) pounds, and yet all other things being equal, has a lower *protection ballistic limit indicating that the material

*Protection Ballistic Limit (PBL) - of an armor plate is defined as the mean of six (6) velocities, three (3) complete and three (3) partial penetrations, the velocity spread to be not more than 150 ft/sec.

in the E22 shot is being used more efficiently. The 90mm E23 is two (2) inches shorter and one (1) pound lighter than the E22. It has a higher protection ballistic limit than the E22. In observing the firings of the E16, E22, and E23, it has been found that approximately four (4) or five (5) inches of the E16 body is rejected intact and do not enter into the penetration mechanism. There is approximately one (1) inch of the shot body rejected intact following the penetration of the E22. The E23 is totally consumed indicating insufficient length of body. The T82E22 design was based on recovered shot bodies of the E16 where it was estimated that approximately four (4) inches of the shot body was rejected intact. The 90/40mm T82E16, E22, and E23 shot were fired against 3" and 4" of armor plate at 55° obliquity in an effort to determine the optimum L/D ratio for this type of shot. At the present time with the data available from these firings, (Section VI) indications are that it will be possible to predict the length over diameter ratio in order to defeat a particular target at a particular velocity.

## THE COMPLETE FAMILY OF AMMUNITION

There has been considerable discussion whether a fin stabilized projectile can be made as cheaply as a spin stabilized projectile, whether a fin stabilized projectile will

be as accurate as a spin stabilized projectile, and whether a fin stabilized projectile will be as lethal as a spin stabilized projectile. To date, all arguments have been in favor of the spin stabilized projectile and for that reason, in a number of gun-ammunition systems that are being developed, a heterogeneous family of projectiles is being specified.

For the FSDS AP shot, there are a number of advantages that can be realized if a smooth bore gun is developed for use with a complete family of fin stabilized ammunition. For example, a smooth bore gun will be easier to manufacture. It will have longer life. It will retain its accuracy for a longer period of time. It will permit the use of a less expensive FSDS anti-tank round because of multi-piece stamped sabot can be used with a smooth bore gun as against a 4-segment steel sabot which is necessary when using a rifled gun.

At longer ranges, the fin stabilized HE and WP ammunition will have better accuracy and longer range because of lower drag of the fin stabilized rounds. When utilizing high capacity thin walled rotated shell, the accuracy of these projectiles is adequate at ranges up to 1500 yards; beyond 1500 yards the flight characteristics are poor. The fin stabilized projectile on the other hand exhibits good flight characteristics at all ranges

and also acceptable accuracy. It is believed that a complete family of fin stabilized HE and WP ammunition can be designed which will at least compare favorably as to HE capacity, cost, lethality and accuracy with conventional spin stabilized projectiles.

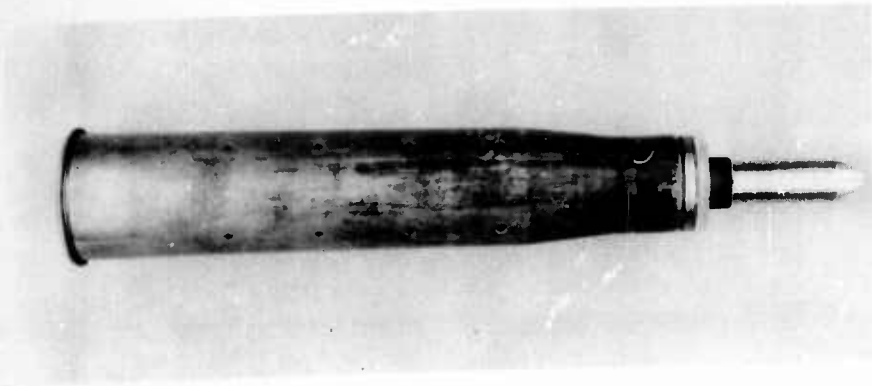
## 90/40MM T82E16

| | |
|---|---|
| **GUN:** | 90mm M3A1 Smooth Bore |
| **MUZZLE VELOCITY:** | 3500 ft/sec |
| **PLATE:** | 3" Rolled Homogeneous |
| **OBLIQUITY:** | 55° |
| **PBL:** | 3250 ft/sec Approximately |
| **SIZE HOLE:** | 4" in Diameter |

| PART | MATERIAL | WEIGHT |
|---|---|---|
| BODY | 98V65 | 9.873 lbs. |
| SABOT | FS 4140 | 2.90 lbs. |
| TAIL | AL 75ST | 1.187 lbs. |

TOTAL WEIGHT: 13.96 lbs.

WEIGHT IN FLIGHT: 11.06 lbs.



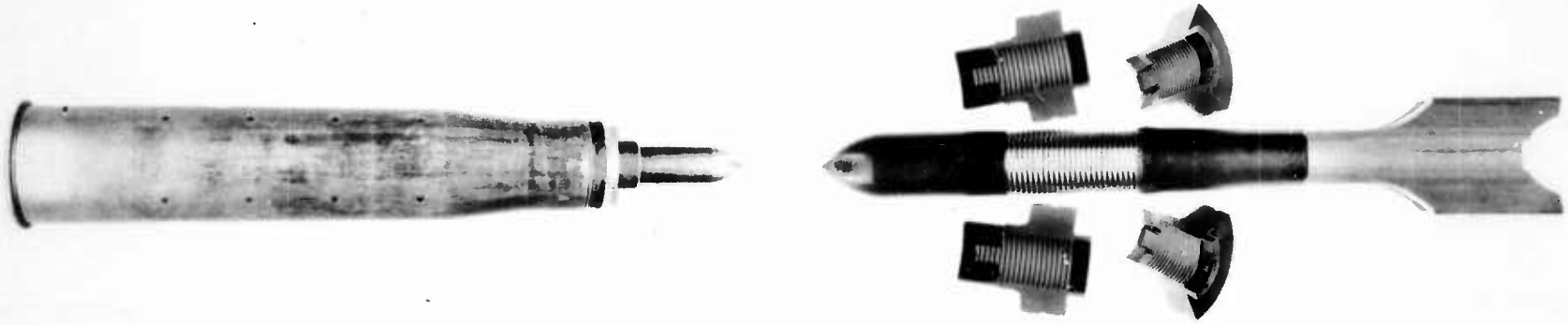
## 90MM T82E22

| | |
|---|---|
| GUN: | 90mm T114 |
| MUZZLE VELOCITY: | 5000 ft/sec Approximately |
| PLATE: | 4" Rolled Homogeneous<br>5" Rolled Homogeneous<br>6" Rolled Homogeneous |
| OBLIQUITY: | 55° |
| PBL: | 4" at 55° 3800 ft/sec approx.<br>5" at 55° 4450 ft/sec approx.<br>6" at 55° No PBL one complete Penetration at 5000 ft/sec |
| SIZE HOLE: | 4" in Diameter |

| PART | MATERIAL | WEIGHT |
|---|---|---|
| BODY | 98V65 | 7.10 lbs. |
| SABOT | FS 4140 | 2.90 lbs. |
| TAIL | AL 75ST | 1.187 lbs. |

TOTAL WEIGHT: 11.19 lbs.

WEIGHT IN FLIGHT: 8.29 lbs.



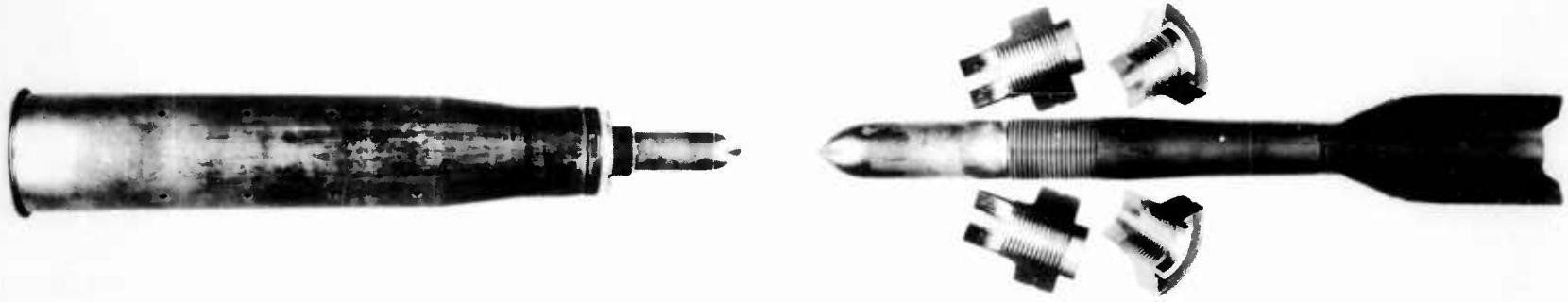
## 90/40MM T82E23

| | |
|---|---|
| GUN: | 90mm M3A1 |
| MUZZLE VELOCITY: | 4400 ft/sec Approximately |
| PLATE: | 4" Rolled Homogeneous |
| OBLIQUITY: | 55° |
| PBL: | 4300 ft/sec Approximately |
| SIZE HOLE: | 4" in Diameter |

| PART | MATERIAL | WEIGHT |
|---|---|---|
| BODY | 98V65 | 6.0 lbs. |
| SABOT | FS 4140 | 2.90 lbs. |
| TAIL | AL 75ST | 1.187 lbs. |

TOTAL WEIGHT: 10.09 lbs.

WEIGHT IN FLIGHT: 7.19 lbs.



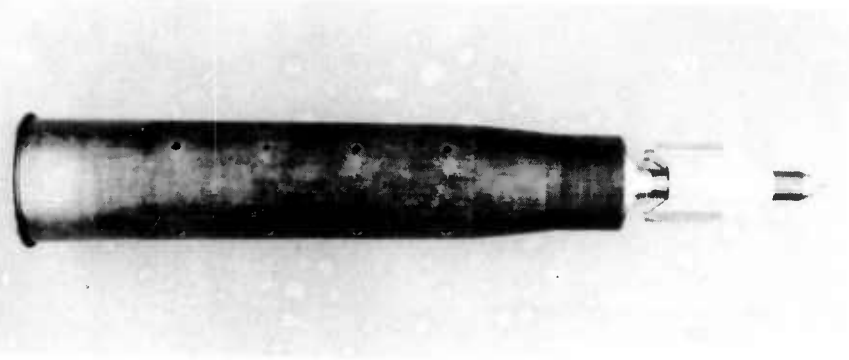
90/40MM T230E1

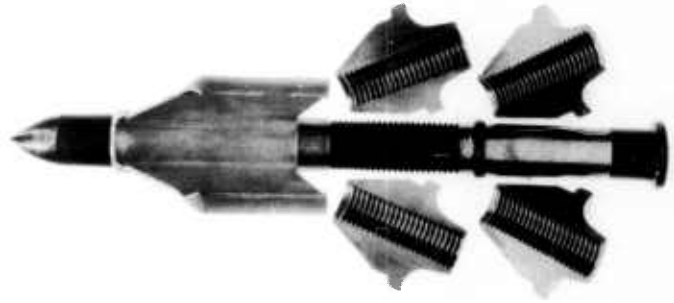
NO FIRING RESULTS

| PART | MATERIAL | WEIGHT |
|---|---|---|
| CORE | Tungsten Carbide | 3.75 lbs. |
| BODY | FS 4140 | 2.34 lbs. |
| SABOT | FS 4140 | 2.90 lbs. |
| TAIL | AL 75ST | .90 lbs. |

TOTAL WEIGHT: 9.89 lbs.

WEIGHT IN FLIGHT: 6.99 lbs.





90/30MM T82E29

NO FIRING RESULTS

| PART | MATERIAL | WEIGHT |
|---|---|---|
| BODY | FS 4150 | 3.50 lbs. |
| SABOT | FS 4140 | 3.00 lbs. |
| BUMPER | FS 1030 | .25 lbs. |
| TAIL | AL 75ST | .40 lbs. |

TOTAL WEIGHT: 7.15 lbs.

WEIGHT IN FLIGHT: 4.15 lbs.

DEVELOPMENT OF A 90MM SHOT ARMOR PIERCING FIN STABILIZED DISCARDING SABOT FOR THE DEFEAT OF ARMOR

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